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ABSTRACT

This study investigated the extent of forward shaping due to post-questions on (1) focussing Canadian chemistry students' (N=109) attention on different and similar categories of information (for example, kinds of chemical reactions) described in a science text and (2) requiring students to process science information at high/low knowledge and high/low comprehension levels. Students were randomly assigned to one of six groups: control, reading-only, and one of four post-questions groups. Students in the latter groups read a chemistry text interspersed with post-questions measuring knowledge or comprehension. A posttest was administered consisting of all four types of post-questions used during instruction. Results indicated that students' scores on the post-test were higher on post-test items from a different category than the inserted questions, suggesting that post-questions inserted in a chemistry test can induce a learning set influencing students' attentional processing. (Author/JN)

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THE UNIVERSITY OF CALGARY

ANALYSIS OF STUDENT FOCUSSING BEHAVIOUR USING POSTQUESTIONS AND CHEMISTRY LEARNING MATERIALS

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by

AUDREY MARIE CHASTKO

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

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DEGREE OF MASTER OF SCIENCE

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THE UNIVERSITY OF CALGARY

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "Analysis of Student Focussing Behaviour Using Postquestions and Chemistry Learning Materials," submitted by Audrey Marie Chastko in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

The purpose of this study was to investigate the learning and instructional effects of postquestions on helping students to focus their attention on categories (e.g. reaction identification) of information contained in chemistry texts, while helping students learn this textual material in different ways. The effectiveness of postquestions was examined in terms of four interactive and two main effect hypotheses. An extensive pilot study was conducted to ensure the development of adequate chemical texts and questions. Subsequently, 109 students participated in the experiment. These students were enrolled in chemistry at three rural senior high schools. They were randomly assigned to one of six groups; one placebo-control group, one reading-only group control group, and one of four postquestion groups. These latter groups read a chemistry text interspersed with postquestions measuring knowledge or comprehension. The postquestions focussed students' attention on one of two categories of information. This arrangement permitted the evaluation of the four interactive hypotheses containing postquestions and posttest items requiring students to process different categories of information at different levels of cognition. Specifically, students in these groups were presented a series of five training (instructional) passages each followed by one of four kinds of postquestions. Review of the text was

prohibited. The dependent variable was the learned information found in a sixth transfer passage and was evaluated using a posttest consisting of all four types of post-questions used during instruction (training). As predicted, students' treatments and posttest scores significantly ($p<0.05$) interacted in three of the four conditions (K-PQ X K-PT, K-PQ X C-PT, C-PQ X C-PT, where K = knowledge, PQ = postquestion, PT = posttest, and C = comprehension). Under these conditions students' scores were higher on post-test items from the same category as the inserted questions and lower on posttest items from a different category than the inserted questions. The one exception was the knowledge X comprehension interaction. All scores of students in treatment groups were in the same "range" or significantly higher ($p<0.05$) than the scores of the reading-only control group. Posttest scores of students in all other groups far exceeded the scores of the placebo-control group. The results of this study suggested that postquestions inserted in a chemistry text can induce a learning set influencing students' attentional processing. Science educators should be aware of the importance of determining which information they most want students to learn and at what level of cognition. Furthermore, questions should be designed to promote attentional processing of conceptually important information.

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"No bird soars too high,
if he soars with his own wings."

This work imperfectly reflects a special kind of vision, wisdom, and encouragement, and is dedicated

to

the memory of my father,

Tony Wachal

who was able to see only the beginning of this project,

but, who

long ago, taught me to fly;

and to

my husband, Tony

and

my children, Ann-Marie, and Paul

who

each in different ways,

at considerable personal sacrifice,

allowed me to soar.

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Chapter 1

INTRODUCTION TO THE STUDY

The present thesis examined research problems dealing with students' ability to focus attention on and remember written materials commonly used in science classrooms. Outlined in Chapter One is an approach borrowed from the field of psychology which has demonstrated reasonable success in investigating non-science prose. Here, specific features of adjunct questioning techniques are presented in relationship to this study. Finally, the research hypotheses tested in this experimental investigation are stated.

LEARNING FROM WRITTEN MATERIALS IN SCIENCE EDUCATION

The emphasis on "meaningful learning" proposed by Ausubel (1963) served to focus inspection upon the organization of written materials provided to students. In addition, Ausubel's concentration upon the existing structure of knowledge and the incorporate of new learning within the students' mind served to promote concern for determining effective methods of presenting information to students.

Indeed, acquisition of information from text passages is an integral part of current educational practice regardless of subject matter content. In summarizing recent re-

search in science education, Gabel, Kagan, and Sherwood (1980) estimated that the largest increase in the number of "teaching-learning strategies" studies they reviewed related to reading and the language arts. Their analysis further evaluated the exploration of the manner in which scientific information is acquired by students using written materials as an imperative goal of future science education studies.

Modern science curricula, according to Welch (1979), require students to process information presented in written form. A large portion of these science materials present some highly complex and sophisticated content. However, Holliday and Braun (1979) suggested that individual teachers and textbook selection committees seemed reluctant to use the available research base when choosing written materials. Wilson and Koran (1976) indicated that many written materials commonly used in science classrooms characteristically ignored important learning considerations. Their appraisal suggested that more effort had been expended on matching written materials with objectives that with incorporating certain variations in these materials which facilitated acquisition of scientific information.

Although learning from written materials may be improved by the constant use of many study aids such as those described by Brown, Campione, and Day (1981), it is

not probable that such extraordinary efforts will be maintained during adult life. Continuation of individual, undirected learning can more confidently be expected to result from experiences producing efficient and effective learning, using written materials, during formal schooling. The production of text materials that maximize student learning of both scientific facts and concepts is an important goal in which teachers, science educators and students share a common interest (Holliday and Benson, (1981). Effective text designs incorporating verbal and visual elements and structures are contingent on a more precise comprehension of the interactions that occur when a student is presented with written materials. Such understanding is rationally dependent upon justifiable knowledge, most economically obtained by controlled evaluations of relevant variables designed to minimize expenditure of time, energy, and money. Incorporation of the available literature concerning generalized learning and instructional theories within the specialized context of scientific facts and concepts is a challenge that merits serious consideration by science educators.

INVESTIGATING STUDENTS' ABILITY TO FOCUS ATTENTION ON WRITTEN MATERIALS

Adjunct Questions

Educational researchers have indeed established a basis for evaluating learning and instructional hypotheses. Recent research literature, exploring the critical aspects of learning from written materials, suggested that a reasonable evaluation of these types of science classroom materials was possible within our current understanding. One of the more successful techniques, used to determine the nature of critical learning activities, such as student behaviours which focus attention, is the periodic insertion of questions throughout a prose passage (Faw and Waller, 1976). The results of experiments using such questions can clarify how students focus attention on different pieces of information in a text, in terms of a variety of criteria such as free recall and knowledge and comprehension posttest questions.

Adjunct questions have been referred to as embedded, inserted, and study questions. Past experimental research has demonstrated that overt responses to adjunct questions produced a consistent facilitation of learning (Anderson and Biddle, 1975). Furthermore, adjunct question studies have employed both prequestions--questions placed before segments of textual material, from one to 15 paragraphs in length, and postquestions--questions which follow similar

segments of textual material.

Early adjunct question studies attempted to identify relevant variables, based on a concern for improving general learning. Question position, type, frequency, and number have been investigated by Frase (1967, 1968, 1971); Rickards and DiVesta (1974), and many others. (See Anderson and Biddle, 1975, for a review of this topic.) More recent studies, such as those by McGaw and Grotelueschen (1972), McConkie, Rayner, and Wilson (1973), Reynolds, Standiford, and Anderson (1979), and Sefkow and Myers (1980), have examined more interesting hypotheses dealing with learning processes in general, and focussing students' attention in particular.

Rothkopf (1966), Rothkopf and Bisbicos (1967), Hershberger (1964), and Frase (1968) demonstrated improved criterion test performance using adjunct postquestions with prose materials as compared to using the same prose materials without questions. Many subsequent studies have supported this earlier work (Dayton, 1977). Early postquestion studies such as those reported by Rothkopf (1966) and Frase (1967) distinquished between direct learning effects and indirect learning effects.

Direct learning effects were indicated, in many postquestion studies, by superior posttest performance on questions requiring answers repeating information previously queried by postquestions. Indirect learning effects,

however, were indicated by posttest performance on questions requiring information not previously queried by postquestions.

For example, a student might be presented with a passage consisting of text segment A and text segment B each containing information category one and information category two, as illustrated in Passage I, Figure 1. Information category one might include proper names of chemists, whereas information category two might include dates of chemical discoveries. Postquestions could require proper name (category one) information following text segment A and date information (category two) following text segment B. A posttest item requiring proper name (category one) information found in text segment A, previously queried by the postquestion following text segment A, would indicate learning resulting from direct instruction; more simply called direct learning. A posttest item requiring proper name (category one) information found in text segment B, not previously queried by the postquestion following text segment B, would indicate indirect learning. Similarly, a posttest item requiring date (category two) information found in text segment B would indicate direct learning, whereas a posttest item requiring date (category two) information found in text segment A would indicate indirect learning.

Rickards (1979) indicated that providing the learner

Text Segment A
Information Category One
Information Category Two

Postquestion following Text Segment A
Information A-Category One

Text Segment B
Information Category One
Information Category Two

Postquestion following Text Segment B
Information B-Category Two

Posttest Items (Criterial Measures)

Information A-Category One [a]
Information A-Category Two [b]
Information B-Category One [b]
Information B-Category Two [a]

[a] If these items are correctly answered, some evidence of a direct learning effect is established.

[b] If these items are correctly answered, some evidence of an indirect learning effect is established.

Figure 1

Evidence of Direct and Indirect Learning Effects-Passage I

with similar types of postquestions consistently requiring information of an identifiable kind over several passages can produce a learning set focussing on the particular kind of information questioned, as illustrated in Passage II, Figure 2. The learning set developed when students focussed attention on specific information, such as proper names, following postquestions is often attributed to the specific forward process (Rickards, 1979). For example, postquestions querying students about proper names (category one) presented in text segments at the beginning of a lesson, as in text segments A and B, often induced students to search for and remember proper name (category one) information later presented in subsequent text segments, as in text segments C and D. Such student behaviour constituted evidence of the learning set-- a specific forward learning process. Posttest items querying the focussed proper name (category one) information, in the example, asked for information found in text segment D not previously queried by postquestions. These items would therefore indicate indirect learning. Posttest items querying information category two found in text segment D, would similarly indicate indirect learning. Category two information, however, would reflect indirect learning of nonfocussed category information.

Anderson and Biddle (1975) estimated the direct learning effect to be approximately four times greater than the

Text Segment A
Information Category One
Information Category Two

Postquestion following Text Segment A
Information A-Category One

Text Segment B
Information Category One
Information Category Two

Postquestion following Text Segment B
Information B-Category One

Text Segment C
Information Category One
Information Category Two

Postquestion following Text Segment C
Information C-Category One

Text Segment D
Information Category One
Information Category Two

Posttest Items (Criterial Measure)

Information D-Category One[a]
Information D-Category Two

[a] If more Information D-Category One is retained, and less Information D-Category Two is retained, some evidence of focussed indirect learning is established (more focussing on Category One, less focussing behaviour on Category Two.)

Figure 2

Evidence of Indirect Learning Effects

(Focussing and Non-focussing Effects)-Passage II

indirect effect. They indicated, however, a potentially greater benefit due to the indirect effect. Clearly, the task of directly questioning every bit of information in a written passage is not only burdensome, but impractical. Only a small number of points can be directly questioned. The indirect influence that postquestions can potentially exert is applicable to selected points of information in the text which are not directly questioned. Postquestions were therefore used in the present study because of their consistent success in producing indirect effects, as indicated by many previous studies (Rickards, 1979).

Rothkopf (1970) identified attention as a primary factor in the learning process. Bransford (1979) also emphasized the importance of attention in learning from text. Many researchers have recognized the need to focus students' attention on the critical aspects of text materials to promote learning. Studies by Rothkopf and Bisbicos (1967),Quellmalz (1972), Reynolds, Standiford, and Anderson (1979), and Holliday and Benson (1981) demonstrated that providing students with questions about restricted categories of information can strongly influence students' attention and recall of information. Furthermore, the nature of learning activities involved in the production of indirect learning effects have been a major concern in attentional research (Anderson and Biddle, 1975; Rickards, 1979). In the present study, the use of postquestions was

designed to optimize the indirect learning effect in order to clarify our understanding of students' focussing behaviours on particular categories of information presented by written science passages. These postquestions were also used to investigate students' ability to remember and transfer a category of information learned from chemistry text to a criterial task evaluating the same and different levels of learning.

Educational Significance

Reynolds, Standiford, and Anderson (1979) predicted that findings from postquestion studies suggested improved student recall of specific categories of information and were important and relevant to classroom learning practices. The written materials used in science classrooms vary both in purpose and design from texts used in previous studies such as narrative prose passages employed by most psychologists reporting attentional research using postquestion techniques. In addition, the verbatim questions used by Reynolds et al. (1979) required rote recall of information in a form similar to that in which the information was presented in the text. Although, such questions have provided much useful and necessary information regarding the function of postquestions interspersed throughout a text, these research findings were restricted in their applicability to classroom oriented educational goals (Felker and Dapra,

1975). Classroom educators are more concerned that students understand a principle or concept well enough to be able to apply it to a new situation (Watts and Anderson, 1971).

Additional research regarding the generalizability of findings to questions requiring more than verbatim recall of information has potential theoretical and practical implications for the attention shaping hypothesis such as that dealing with specific forward processing. Comprehension and knowledge questions each require different levels of processing (Craik and Lockhart, 1972). Knowledge questions have been used in a number of adjunct question studies (Rothkopf and Bisbicos, 1967; McGaw and Grotelueschen, 1972; Reynolds, Standiford, and Anderson, 1979; and many others). These questions, however, may be answered on the basis of perceptual or phonological encoding and do not necessarily require comprehension of a concept or principle, according to Anderson (1972). Furthermore, Anderson (1972) asserted that assessment of the comprehension of a concept or principle can be achieved by requiring the application of that concept or principle to a new example. The extent to which various levels of postquestions, querying information within a specific category, succeed in facilitating performance on posttest knowledge and comprehension questions is an important factor in determining the nature of attentional behaviour in relation to the specific forward

process.

Some of the questions constructed for this investigation consisted of rearranged or reordered sentences and phrases from the written text materials. These reordered-type questions required students to demonstrate knowledge of the concepts described in situations identical to the examples provided in the written materials. However, such questions failed to meet the criteria suggested by Anderson (1972) for comprehension questions. Thus, these simpler questions are referred to as knowledge questions in the present study. On the other hand, questions that required students to apply the concepts described in the written materials to situations that were different from the examples provided in the text passages of this present study are called comprehension questions, as recommended by Anderson (1972).

DESIGN CONSIDERATIONS

Main and Interactive Hypotheses

Researchers attempting to support learning and instructional hypotheses in adjunct question studies often lacked adequate controls, as indicated by McConkie (1977). Rickards (1979) argued that postquestion studies should include a reading-only control group so as to establish a base line allowing researchers to demonstrate any effect of post-

questions on criterion posttest measures of students' performance. More new and interesting information has been provided by studies such as those of Reynolds, Standiford, and Anderson (1979) which have incorporated improved designs using control groups and evaluating interactive hypotheses. Using simple interactive hypotheses directly attacks some of the design problems often characteristic of selective attention studies. For example, an interactive design reduces the need to control for item difficulty among different postquestions. More importantly, this type of design circumvents the problem that can occur when postquestion treatments increase the retention of targeted information to the detriment of nontargeted information. Examples of targeted information might include dates, places, or names, presented in texts. These information categories can be used as a basis for generating different kinds of postquestions. Indeed, the possibility that learning of nontargeted information might be depressed below the level of the control group, due to the specific forward effect, has been suggested by Rickards (1979).

Task Structure

A second aspect dealing with adjunct postquestion study designs merits consideration. Carver (1972) stated that there is reason to believe that the role of adjunct postquestions has remained somewhat ambiguous to the typi-

cal subject participating in many postquestion studies. McConkie (1977) recommended effective manipulation of the task structure to allow subjects to identify the nature of the task and to adjust their activities on the basis of repeated participation in the experiment under constant conditions. These recommendations underscored the need to refine the sensitivity of the indirect effects produced by specific forward processes in assessing the attention shaping hypothesis.

IN CONCLUSION

The selection and use of written materials used in science classrooms can benefit from an increased understanding of the processes that are involved in student learning from written materials (Holliday, 1981). The well-established psychological technique of asking adjunct postquestions is available with which to begin such investigations. Now seems to be a reasonable time for science educators to evaluate the written materials they use, in relationship to some of the questions that psychologists have been examining over the past twenty years, according to Holliday and Benson (1981). Existing knowledge concerning the effects produced by specific forward processing constitutes a framework with which to extend understanding of attentional behaviours affecting the learning of science

information.

PURPOSE OF THE STUDY

The general purpose of this study was to determine the indirect learning effects of postquestions in helping students shape their attending behaviours on text describing chemistry concepts, similar to texts used in the classroom. The technical purpose of this study was to determine the extent of forward shaping due to postquestions:

1. focussing students' attention on different and similar categories of information (e.g. kinds of chemical reactions) described in a science text, and
2. requiring students to process science information at the knowledge and comprehension levels.

Four interactive hypotheses were developed for this purpose in which a specific category of information at specific levels of processing was queried using postquestions and later evaluated using a variety of analogous posttest items.

STATEMENT OF THE HYPOTHESES

It was hypothesized that students assigned to four postquestion treatment groups (independent variables)--knowledge, targeted category one; knowledge, targeted cate-

gory two; comprehension, targeted category one; comprehension, targeted category two, would differentially respond to four analogous posttest items (dependent variables). Specifically, it was hypothesized that students who were provided with postquestions querying one category of information in a text would attend more to that information category than the nontargeted, alternative category two. Conversely, students who were provided with postquestions querying the alternative category two of information would attend more to this alternative category. Thus, it was expected that students would correctly answer more posttest items querying the same information category focussed on by the provided postquestion type while answering correctly fewer posttest items querying the information category not focussed on by the provided postquestion type. This general expectation formed the basis for four specific interactive hypotheses dealing with the results of providing:

1. knowledge postquestions and knowledge posttest items.
2. knowledge postquestions and comprehension posttest items.
3. comprehension postquestions and knowledge posttest items.
4. comprehension postquestions and comprehension posttest items.

In other words, the following hypotheses were tested, as

illustrated in Figure 3.

1. Students provided with knowledge postquestions will generate higher scores on knowledge posttest items focussing on the targeted information category dealt with in the postquestion. In contrast, students provided with knowledge postquestions will generate lower scores on knowledge posttest items focussing on the nontargeted information category dealt with in the postquestion.

2. Students provided with knowledge postquestions will generate higher scores on comprehension posttest items focussing on the targeted information category dealt with in the postquestion. In contrast, students provided with knowledge postquestions will generate lower scores on comprehension posttest items focussing on the nontargeted information category dealt with in the postquestions.

3. Students provided with comprehension postquestions will generate higher scores on knowledge posttest items focussing on the targeted information category dealt with in the postquestions. In contrast, students provided with comprehension postquestions will generate lower scores on knowledge posttest items focussing on the nontargeted information category dealt with in the postquestion.

GROUPS	POSTTEST ITEMS			
	Knowledge Level		Comprehension Level	
	Category One	Category Two	Category One	Category Two
Knowledge Level Category One	High	Low	High	Low
Knowledge Level Category Two	Low	High	Low	High
	(Hypothesis 1)		(Hypothesis 2)	
Comprehension Level Category One	High	Low	High	Low
Comprehension Level Category Two	Low	High	Low	High
	(Hypothesis 3)		(Hypothesis 4)	
No Questions Reading-Only Control	a	a (Main-Effect Hypothesis 1)	a	a
No Questions or Reading Placebo-Control	b	b (Main-Effect Hypothesis 2)	b	b

a Denotes the same or lower scores than scores in the column above

b Denotes lower scores than all scores in the column above

Figure 3

Interactive and Main-Effect Hypotheses

4. Students provided with comprehension postquestions will generate higher scores on comprehension posttest items focussing on the targeted information category dealt with in the postquestion. In contrast, students provided with comprehension postquestions will generate lower scores on comprehension posttest items focussing on the nontargeted information category dealt with in the postquestions.

Furthermore, the following main-effect hypotheses were proposed and tested:

1. It was hypothesized that students' performance in the treatment groups on each dependent variable would be the "same" or "higher" than that of the reading-only control group.

2. It was hypothesized that students assigned to the reading-only control and treatment groups will outperform students assigned to the placebo-control group.

Chapter 2

THEORETICAL CONSIDERATIONS AND REVIEW OF THE LITERATURE

The literature concerning learning from text presents well documented evidence supporting the need to ensure that students attend to important features of text material. The most widely cited theory relating to the use of questions adjunct to written materials is that proposed by Rothkopf (1965).

Rothkopf's theory is based on the idea that the effectiveness of instructional situations is mediated by the learner's perception of the instructional task requirements. The provision of instructional materials is theorized to arrange potential stimulation of students. Rothkopf (1968) maintained that attentional processes were used by the learner to transform this stimulation into effective learning activities.

Anderson (1970) identified at least two aspects of attention. First, the student must be oriented toward the instructional stimulation provided by the materials. Observable behaviours, such as eye movements, are often used as indicators of this orientation. Learning likely occurs when the observable orientation is followed by an unobserable encoding of the information presented in the materials. Clearly, the mere provision of instructional materials does not automatically result in effective learning in all sit-

uations. Rothkopf (1970) maintained that what the students do with learning materials determines, to a large degree, what is learned, and that controlling the learning activities of the student can directly influence student recall of the information presented in the materials. He further considered the use of adjunct questions a powerful mechanism for influencing student learning activities.

EXPLANATIONS OF THE EFFECTS OF ADJUNCT QUESTIONS

The Selective Attention Model

Attempts to explain the effects of prequestions and postquestions in the facilitation of learning have met with varying degrees of success. Certainly, understanding how adjunct questions work is an important determinant in the proficient manipulation of the identified relevant variables. An examination of the theoretical explanations found in the literature was undertaken to facilitate the analysis of the attentional processing activities produced by adjunct postquestions.

A selective attention model has been consistently used to explain the direct effects found with prequestions as compared to the direct and indirect effects associated with postquestions. Rothkopf (1971) suggested that prequestions probably alerted the learner to information that was considered important. The learners read the passage to select

only this cued information and often did not attend to other content. Postquestions, on the other hand, could not direct the learners to any specific information contained in the questioned paragraph, so that attention to all of the information often resulted in increased direct and indirect learning, according to Rothkopf (1971). Based on prequestion research, the superior performance of prequestion treatments on posttests measuring information directly queried by prequestions was attributed to the learner attention induced by prequestions, in the view of Wittrock and Lumsdaine (1977). Although this selective attention model can be used to predict the different effects of prequestions and postquestions (Sefkow and Myers, 1980), Wittrock and Lumsdaine (1977) suggested that the functioning of postquestions has not been conclusively delineated.

The results of studies investigating the indirect effect of postquestions, have indeed been divergent. Anderson and Biddle's (1975) review of postquestion studies reported a facilitative indirect effect in a majority of studies. McConkie's (1977) analysis of studies conducted since 1970, however, suggested that many no-question control groups outperformed postquestion treatment groups on information not directly related to postquestions. Rothkopf (1970) perceived an adaptive character in learning activities but indicated that specific situations might result in either positive or negative effects. Apparently,

the production of a facilitative indirect effect requires sensitive attentional manipulations of a nature not yet fully ascertained (Bull, 1973).

Processing Initiated by Postquestions

Frase (1967) proposed that the direct and indirect effects of postquestions could be accounted for either by "backward" or "forward" processing. The backward hypothesis suggested that students provided with postquestions implicitly reviewed the content in the passage they had just read before they encountered the postquestions. The mental rehearsal and review of this passage increased retention of the information presented in the passage and produced superior performance on criterion posttest measures. In contrast, the forward hypothesis suggested that students answering postquestions inserted after initial text segments often focussed attention on subsequent text segment information of a specific or general type. Students' orientation toward increased attention could improve the learning of information in the passages following the postquestions. Later investigations prompted Frase (1970) to suggest that the effect of postquestions might be due to some combination of both forward and backward processes.

Postquestion studies designed to permit simultaneous examination of possible forward and backward effects of postquestions provided evidence suggesting the presence of

both backward and forward processing when students encountered postquestions. McGaw and Grotelueschen (1972) demonstrated that backward processing can produce an indirect learning effect due to a general backward review, affecting information spatially or thematically related to information directly questioned by inserted adjunct postquestions. Similar results were also found by Rothkopf and Billington (1974). Direct learning of specific information questioned by inserted postquestions can result from a specific backward process demonstrated by Rickards and DiVesta (1974).

Specific forward processing was also evident in the Rickards and DiVesta (1974) study which indicated that increased attention to material following inserted postquestions can result in indirect learning affecting certain cued information found in the subsequent passage. General forward processing, as demonstrated by McGaw and Grotelueschen (1972), can also result in indirect learning affecting other uncued information found in the passage subsequent to postquestions. This indirect learning is theoretically initiated by increased attention to material following inserted postquestions. As the present study examined the forward shaping hypothesis in relation to the processing of specific written science information a detailed examination of the forward hypothesis and the studies to assess specific forward processing was undertaken.

FORWARD PROCESSING

The Forward Shaping Hypothesis

The forward hypothesis proposed by Rothkopf (1965) and discussed by Frase (1967) suggested that students answering postquestions after initial text segments often focus attention on subsequent text information of a specific or general type. Specific forward processing occurs when students provided with postquestions inserted in the initial text segments learn the same kind of specific information presented in later text segments. For example, a postquestion requiring a technical term or proper name answer might suggest that this information should be attended to in the following text segment if that segment contained technical term or proper name information. The ability to answer a postquestion using a specific type of information in the next text segment would reassure the learner that attention to the specific type of information was an appropriate learning behaviour. Theoretically, similar processing activities would be used when subsequent text segments were encountered. Thus, postquestions can provide hints or cues to the learner regarding the type of information that might be considered important in answering subsequent postquestions related to subsequent passages. Attention to these cues by students can result in the establishment of a learning set where attention is focussed on a specific cate-

gory of information. A learning set can be induced when the same kind of information is repeatedly questioned in a series of text segments (Rickards, 1979).

Postquestion Studies Investigating the Specific Forward Process

Rothkopf and Bisbicos (1967) reasoned that specific forward processing could be expected to result in better posttest performance in text segments presented in the last half of a passage than on the text segments presented in the first half of a passage. Indeed, posttest performance was better in the last six text segments relative to the first six text segments used in this experiment. Posttest items queried different specific information from the same category as the information directly queried by the post-questions. The "selective facilitation effect" was, therefore, attributed to the indirect learning effect rather than to a direct learning effect. The indirect learning effect likely operated in a forward direction to produce better performance on the later text segments after the learning set had been established.

The approach used by Rothkopf and Bisbicos (1967) required the observation of performance changes across a series of text segments. Another approach, based on the superior performance in the latter segments of a series of text segments, demonstrated by Rothkopf and Bisbicos (1967),

has been used by McConkie, Rayner, and Wilson (1973) and Mayer (1975). Students participating in these studies received several passages or text segments interrogated by postquestions inserted after each of the passages. The postquestions consistently asked for the same type of information in each of the passages. Evaluation of indirect learning of the targeted information type was then ensured by testing student performance on only the last passage or passages in the series. Thus, students were provided with the opportunity to establish a learning set to attend to a specific type of information in the earlier or training passages and were required to demonstrate the learning of the information on the later or transfer passages.

Mayer (1975) used the training-transfer passage design to evaluate questions manipulating the level of understanding. Eight passages were used in this study. The first six training passages were followed by a single type of postquestions. The seventh and eighth transfer passages were followed by all types of postquestions. Postquestions following passages seven and eight constituted a posttest evaluation of student performance.

Subjects in the postquestion treatment groups of this study performed best on the kinds of questions they had received in the first six training passages dealing with mathematical probability concepts. However, students receiving postquestions requiring a mathematical calculation or a de-

finition of mathematical term answer performed below the control group on posttest questions requiring the use of a mathematical model. The "Model" group, required to use a mathematical model to answer postquestions, successfully answered definition and especially calculation posttest questions.

Students in the "Model" group apparently established a learning set to understand the concept presented in the training passages. They spent less time reading transfer passage eight than transfer passage seven. Evidently, the established learning strategy developed during reading of the training passages was also used during reading of the transfer passages. The learning resulting from anticipation of model questions enabled students to readily answer posttest items questioning other less demanding transfer passage information. In contrast, "Calculation" and "Definition" groups developed an evidently more limited learning strategy that proved insufficient to cope with the more comprehensive requirements of the model questions. These groups required more time to read the eighth transfer passage after they had been exposed to the model questions in the posttest items presented after transfer passage seven.

Strong support for the forward shaping hypothesis was demonstrated in a recent study by Reynolds, Standiford, and Anderson (1979), according to Sefkow and Myers (1980). Rote-learning questions requiring the same restricted cate-

gory of information were provided after each of 12 text information segments presented by a computer terminal. The data suggested that students engaged in a time-intensive process when information relevant to targeting postquestions was encountered. Students receiving postquestions spent more time reading information relating to all of the categories targeted by postquestions than did the reading-only control students. Furthermore, each postquestion group consistently spent more time reading the information relating to their targeted category than they spent reading information relating to other targeted categories. Total time required by postquestion groups was the same as the time required by the reading-only control group, excluding time required to answer questions.

Posttest item performance is, however, of more interest to the present study. Student performance on repeated and new posttest items was significantly better for the category of information targeted by postquestions in the treatment groups than in the reading-only control group. Repeated posttest items consisted of questions previously used as postquestions. New posttest items consisted of questions querying similar information in the categories targeted by the postquestions of the treatment groups. This superior performance was demonstrated by an interactive comparison of the postquestion group and type of posttest item. The effect was larger for repeated posttest

items than for new posttest items. The larger effect of repeated posttest items was attributed to the well-established larger effect of direct learning relative to indirect learning. The smaller effect demonstrated for the new posttest items, nevertheless, supported the focussing of indirect learning expected in the present study as a result of targeting specific categories of science information by the use of postquestions.

The focussing behaviour produced by postquestions targeting specific categories of information was further extended by Holliday and Benson (1981) to a science instructional chart-table medium. Students in this study also differentially responded to different categories of posttest items targeted by postquestions. Interactive comparisons demonstrated that students performed significantly better on the posttest items querying information from the same category as the postquestions they had received. Posttest items querying information from the other category of information targeted for another postquestion treatment group were correctly answered less frequently. Students, evidently focussed attention on the category of information targeted by postquestion treatments. The demonstrated focussing behaviour was stronger for the instructional chart-table medium than that expected for a text medium, as indicated by Holliday and Benson (1981).

The enhanced influence of postquestions on students'

attending behaviours shown in this study was attributed to the combined effects of the chart-table medium and two features incorporated to clarify students' perceptions of the nature of the learning task. Initially, all students in the postquestion treatment groups were permitted to practice their respective treatment tasks for the first seven vitamins presented in the instructional chart-table. Subsequently, four different orienting directions were provided to the students concerning the posttest evaluation measure. The posttest measure required students to complete an empty vitamin chart matrix when provided with a listing of the appropriate attributes.

Implications of the Related Literature Review

On the basis of the preceding literature review, several statements can be made that have a direct influence on the present study investigating the learning effects of postquestions in shaping students' attending behaviours on chemistry concepts. First, targeting a specific category of information by consistently providing the same type of postquestions for several passages of text information can produce a learning set whereby students' attention focussed on that type of information. This focussing behaviour has been supported in varying degrees by the studies of Rothkopf and Bisbicos (1967), McConkie, Rayner, and Wilson (1973), and Reynolds, Standiford, and Anderson (1979) using narra-

tive passages; Mayer (1975) using passages designed to teach mathematics concepts; and Holliday and Benson (1981) using a science instructional chart-table. A similar focussing behaviour was expected in the present study using written materials, similar to those used in science classrooms, targeted by postquestions requiring specific categories of chemistry related information.

In addition, the effects of such targeting postquestions were expected to be most apparent in the later segments of the experimental passage used in the present study, as indicated by Rothkopf and Bisbicos (1967). Focussing behaviour can be effectively demonstrated by interactive comparisons of criterion posttest measures using different categories of targeted information found in the instructional medium, as shown by Reynolds, Standiford, and Anderson (1979) and Holliday and Benson (1981). The use of interactive comparisons was therefore adopted as a means of assessing the indirect learning effects of focussing behaviours predicted in the present study.

Second, the categories used to target information in shaping attention behaviours must be clearly distinquishable, as suggested by McConkie (1977). Rothkopf and Bisbicos (1967) successfully demonstrated an indirect learning effect using the more readily identifiable "measure" and "name" postquestions but they did not show evidence of an indirect effect with the less readily identifiable "common

phrase" and "technical term" category of postquestion. McConkie, Rayner, and Wilson (1973) similarly found that a more readily identifiable "Number" postquestion treatment more effectively developed a learning set in specific forward processing than did a "Combined" postquestion treatment which they perceived to have generated the greatest uncertainty in cueing a specific category of information. These results influenced the decision, in this present study, to conduct preliminary field testing, aimed at determining the most appropriate categories of information later used in the experimental investigation.

Third, support for the forward shaping hypothesis has been provided by researchers using questions that required rote learning of factual information. Some of the postquestions used successfully to target restricted categories of information included name and measure verbatim questions (Rothkopf and Bisbicos, 1967); number, factual, and structure rote-learning questions (McConkie, Rayner, and Wilson, 1973); and technical term, number, or proper name rote-learning questions (Reynolds, Standiford, and Anderson, 1979).

Specific forward processing effects were produced by Rickards and DiVesta (1974) using postquestions requiring meaningful learning. In addition, Mayer (1975) indicated the development of a learning set in students who were provided postquestions requiring the application of a math-

ematical model. However, little work has apparently been done investigating the shaping behaviours produced by questions requiring comprehension learning. This present study, therefore, attempted to extend the understanding of the processes engaged by students required to answer comprehension postquestions and comprehension posttest items.

Finally, indirect effects can be readily assessed by evaluating performance on only the last passage of an experimental text using postquestions that required specific categories of information. The evaluation of student performance on posttest items relating to the transfer passages of the McConkie, Rayner, and Wilson (1973) study unequivocally measured the indirect learning produced by the specific learning set developed in the forward direction. In contrast, Reynolds, Standiford, and Anderson's (1979) evaluation of repeated and new items over all passages used in their experiment and Holliday and Benson's (1981) chart-table recognition evaluation on the last seven vitamins presented in their study produced both direct and indirect learning effects. The interactive comparisons in these studies involved comparing student performance on repeated posttest items with student performance on new posttest items. The repeated posttest items queried the same information required to answer previously encountered postquestions dealing with the targeted information category and reflected direct learning. The new posttest items, how-

ever, queried information from a different category not encountered in previous postquestions and reflected indirect learning. As the present study was concerned with the indirect learning effects produced by the specific forward process, it was necessary that indirect learning of the targeted information category be compared with indirect learning of the nontargeted information category.

The interactive comparison of new posttest items by Reynolds, Standiford, and Anderson (1979) clearly measured indirect learning of targeted information categories and nontargeted information categories. The specific forward processing may, however, have been adversely affected by an increased influence of specific and general backward processing. The requirement to remember information contained in the previous 11 text segments of the passage would likely have initiated an extensive memory search at the time of the posttest. Sefkow and Myers (1980) demonstrated the necessity of providing experimental conditions that ensured questioned information was still available in the students' memory at the time of evaluation. Larger and more reliable focussing effects than those produced by Reynolds et al. (1979) could perhaps be demonstrated in the present study, for posttest items querying information indirectly related to the targeting postquestions by evaluating student performance on only the last passage of the experimental text.

TASK STRUCTURE

McConkie (1977) described the problem of task structure ambiguity in his analysis of previous postquestion studies. He indicated that students generally exhibited a high degree of cooperation and attempted to modify their behaviours to maximize performance based on their perception of the task structure. Different students adopted different strategies when the nature of the learning task was not clearly understood or when student expectations were at a variance with the task defined by the experiment. As a consequence, the development of effective strategies required several trials in a study by McConkie and Rayner (1974).

McConkie (1977) suggested reducing the ambiguity of the task in future postquestion studies by informing the students of the nature of the evaluation task criterion before the experiment. A similar reduction of task ambiguity can also be accomplished by allowing the students to participate in several trials under constant conditions before evaluation of their performance at the end of the experiment. He further suggested that the potential capacity of the forward processing effects of postquestions could be more effectively assessed by the use of practice passages that consistently employed the same identifiable type of postquestions. In addition to cueing the nature of information most likely tested, such practice passages were also

seen to serve as an efficient mechanism for allowing students to judge the effectiveness of adopted learning strategies and to make appropriate adaptations in the successive practice passages. Indeed, Holliday and Benson (1981) attributed at least part of the strong focussing behaviour evident in their study to the effort made to reduce task ambiguity.

In summary, these considerations of the effects of task structure when combined with the implications resulting from the literature review of forward processing studies favoured an experimental design composition which included several training practice passages and evaluation of learning in only the last or transfer passage.

LEVELS OF QUESTIONS

Comprehension Questions

The type of question commonly used in research studies has been a concern to educators evaluating the implications of focussing behaviours in classroom learning. The literature review of the previous section supported the observations (Watts and Anderson, 1971; Felker and Dapra, 1975) that most postquestion studies have emphasized the rote learning of information. The present investigation of focussing behaviours evaluating indirect learning at the comprehension level attempted to extend the accumulated research. Research using comprehension postquestions has not

been extensive, although Rickards (1979) noted a recent trend to the use of questions other than those at the verbatim level. The few published studies involving comprehension level questions found in the literature have not yet provided a definitive evaluation of the effects associated with the use of these kinds of questions.

Postquestion Studies Involving Comprehension Questions

A doctoral dissertation by Quellmalz (1972), cited by Anderson and Biddle (1975) and Reynolds, Standiford, and Anderson (1979), used postquestions requiring the rote learning of proper names and other postquestions requiring the identification of a new example of a concept or principle (comprehension level learning). Performance on new "proper name" posttest items querying information indirectly related to the postquestions was significantly higher in those text segments where "proper name" postquestions had been asked and in identification of "new-example" new posttest items in the text segments where identification of "new-example" postquestions had been asked.

These results provided additional support for expected student focussing behaviours in the present study. The effects produced by Quellmalz (1972) using rote-learning "proper name" postquestions were consistent with those demonstrated by Reynolds, Standiford, and Anderson (1979) using rote-learning postquestions in focussing new posttest item

responses. The present study predicted differential responses in knowledge level posttest items using knowledge level postquestions. A similar facilitation of indirect learning evaluated by new comprehension level posttest items, was also predicted, using comprehension level postquestions. Comprehension level "new-example" postquestions used by Quellmalz (1972), indeed, facilitated comprehension level "new-example" posttest responses and supported the expectation of the present study.

Watts and Anderson (1971) investigated the effects of comprehension postquestions requiring the application of text information to examples different from those used in the passage. Overall posttest performance by students in the two application postquestion treatment groups was superior to that of two repeated-example postquestion and a single name postquestion treatment groups. Application postquestion groups performed significantly better on posttest items repeating questions previously used as postquestions. A similar superior performance by application postquestions groups was demonstrated on the application posttest items not previously answered as postquestions. In addition, these application postquestion groups scored as well as the repeated-example postquestion groups on the repeated-example posttest items and as well as the name postquestion group on the name posttest items. These results provided support for the idea that requiring students

to answer comprehension level questions facilitated later performance on questions requiring comprehension and rote level learning.

An analysis of posttest performance on the items received by each treatment group during instruction in the Watts and Anderson (1971) study failed to reveal any increase in performance over the successive passages and was used to justify the rejection of the forward shaping hypothesis and subsequent consideration of a backward review influence in the study. This analysis of student performance over the successive passages, however, reflected direct learning. No similar analysis was made on the posttest items not previously answered as postquestions. Therefore, no evaluation of the forward shaping hypothesis was made for the indirect effect of comprehension or knowledge level questions. The indirect effect is a major concern of the present study.

Felker and Dapra (1975) provided additional support for the facilitative effects of comprehension postquestions requiring identification of a new instance of either a concept or a principle as compared to verbatim questions. Students were evaluated on problem-solving tasks requiring recall and application of rules in novel problem situations and detection of errors in rule usage or sequencing. In addition, these students were evaluated using new verbatim and comprehension multiple choice posttest tasks. Comprehension ques-

tions, as shown in this study, influenced processing behaviours that affected problem solving but forced evaluation measures such as those presented by multiple choice test items did not reflect this comprehension as well as the problem solving measures requiring students to apply necessary concepts and rules.

The "level of processing" approach has been used to account for the different effects apparent in the learning produced using comprehension and rote-learning postquestions. This approach suggested that different levels of processing are initiated by rote-learning and comprehension level postquestions. Craik and Lockhart (1972) suggested that phonological or orthographic encoding such as that theoretically initiated by rote-learning or verbatim questions (Anderson, 1972) required only superficial processing and resulted in poorer retention of information. Semantic encoding such as that initiated by comprehension level questions was theorized to produce deeper and more meaningful processing resulting in better retention of information.

A recent study by Andre, Mueller, Womack, Smid, and Tuttle (1980), however, failed to support the facilitative results demonstrated by Watts and Anderson (1971) and Felker and Dapra (1975) with application questions. This study seriously challenged the "application question hypothesis" proposing that later comprehension level performance is better facilitated by questions requiring application learn-

ing than questions requiring factual learning. Andre et al. (1980) reported a series of seven experiments conducted over a three year period comparing the effects of application-to-new- example postquestion treatments to factual postquestion treatments. Both treatments were evaluated by new posttest application questions.

The materials used in the study included the five passages and sets of questions used by Watts and Anderson (1971), and an additional five passages and corresponding question sets constructed in a similar format and style. The seven experiments examined the relationship between type and position of question, the effects of postquestions using a representation memory hypothesis and using a directed attention hypothesis, and the effect of adjunct question difficulty. No significant differences were found, in five of the studies, between student performance in application postquestion treatments and factual postquestion treatments. Two studies demonstrated a superiority for factual postquestion treatments on application posttest items. A meta-analysis of the studies comparing the effects of application and factual questions on application posttest evaluations suggested that there was little evidence to support superior facilitation of later application for either type of postquestions. Such results suggested the possibility that the level of information encoding might not be a discriminating factor in the operation of adjunct postquestions

used in the present study.

In another approach, Morris, Bransford, and Franks (1977) suggested that the different ways of processing information employed by students might be reflected in the relationship between the processing strategies used in the learning task and the strategies required to respond to items on the posttest evaluation. Semantic encoding, from this transfer-appropriate processing perspective, is not necessarily the only meaningful way information is processed. A learning task regarded as superficial from the "level of processing" perspective could be meaningful in achieving a particular learning goal. Meaningful learning, then, reflects the degree to which strategies developed during instruction enable students to acquire information used to perform instructional tasks. Posttests, however, often require students to perform tasks different from those learned during instruction. Such inappropriate transfer tasks inadequately assess learning. More appropriate learning evaluations can be made using posttest transfer tasks requiring the same kind of learned information as instructional tasks.

Students, in the present study, consistently received postquestions requiring answers dealing with the same category of information. Knowledge level postquestion treatments required students to apply the targeted information category to an example presented in the text segment. Com-

prehension level postquestion treatments required students to apply the targeted information category to an example different from those presented in the text segments. Several different learning strategies might have been adopted by these students during the instructional task. Two of the more likely strategies, would probably have involved either attention to the information category or attention to the examples used in the text segments and postquestions. Whereas students were exposed to both information categories found in the text segments, these students were aware of only the one type of example used in postquestions consistently received in their particular treatment. Postquestions, then provided a more discernable basis for determining the importance of the information category than for the type of example.

It was therefore hypothesized that students receiving postquestions over a series of text segments consistently querying specific categories of information would develop a processing strategy that primarily involved attention to a particular information category. A secondary, but more unlikely learning strategy would have isolated the type of situation (e.g. repeated-example or new-example) in which learned information would be questioned.

Research studies such as those of Quellmalz (1972), Reynolds, Standiford, and Anderson (1979), and Holliday and Benson (1981) have provided substantial evidence of student

focussing behaviours in experiments initiating forward processing. Such focussing behaviour has been evident in posttest evaluations at the knowledge level after knowledge level postquestion treatments and at the comprehension level after comprehension postquestion treatments. Similar focussing behaviour was expected, in the present study, where knowledge level posttest items were used to evaluate learning initiated by knowledge level postquestions and comprehension level posttest items were used to evaluate learning initiated by comprehension postquestions. The transfer task used in posttest evaluations of both instances exactly replicated the instructional task presented by the postquestions.

Inconclusive results have been produced by investigations using posttest evaluations at a different learning level than the level of instructional postquestions. Watts and Anderson (1971) indicated that comprehension level postquestions were more effective than knowledge level postquestions in facilitating posttest performance on both comprehension and knowledge level items. Felker and Dapra (1975) and Mayer (1975) reported results consistent with the results of Watts and Anderson (1971). Andre, Mueller, Womack, Smid, and Tuttle (1980) failed to substantiate the superior facilitation of comprehension postquestions relative to factual postquestions reported by Watts and Anderson (1971), although both studies used highly similar mater-

ials.

Investigations of focussing behaviour using posttest evaluations at a different learning level than the level of instructional postquestions were not evident in the related literature. The results of Andre, Mueller, Womack, Smid, and Tuttle (1980), however, suggested that knowledge level and comprehension level postquestions could at least be expected to produce similar comprehension level posttest performance. Furthermore, the transfer-appropriate-processing notion suggested that a well-established learning set focussing attention on a specific information category would enable students to successfully answer questions dealing with that category at both levels of learning. The development of a learning set would occur if the strategy adopted during instruction was one of attending to the cues that established the information category. Students, in the present study, would develop the learning set as a result of answering repeated-example (knowledge level) postquestions or new-example (comprehension level) postquestions. The evaluation transfer task, used in this study, required students to apply the characteristic factors of a restricted information category to a designated example. Therefore, focussing effects were expected in posttest items using new examples (comprehension learning) targeted by knowledge postquestions and in posttest items using repeated examples (knowledge learning) targeted by comprehension postquestions.

SUMMARY

Several adjunct postquestion studies have been examined in this chapter. These studies have provided substantial evidence that postquestions increase effective learning from prose materials. Significant learning implications of such studies can be expected to increase the effective use of written materials in science classrooms.

A selective attention model was used to account for learning effects produced by adjunct prequestions and postquestions. Attentional backward and forward processes theoretically induced by postquestions further helped to explain direct and indirect learning facilitation demonstrated in experimental postquestion studies.

Forward shaping of attention has been theorized to account for focussing on restricted information categories targeted by postquestions. Recent studies have provided empirical support for such focussing behaviours using interactive comparisons of learning evaluations querying targeted and nontargeted information.

The use of several training passages followed by evaluation on a transfer passage has been theorized to reduce task ambiguity and to provide conditions that enhance focussing behaviours during learning. Of particular importance to the present study, the training-transfer passage experimental design additionally ensures evaluation of in-

direct learning.

A survey of the related literature revealed a state of uncertainty regarding the learning effects of comprehension level instructive questions adjunct to prose material. "Levels of processing" and "transfer-appropriate-processing" models examined in this chapter, provided different conceptions of meaningful learning. The consideration of the transfer-appropriate-processing model suggested that focussing effects could be expected in both knowledge level and comprehension level learning evaluations of knowledge level postquestion instructional treatments used in the present study. Similar focussing effects were also predicted in both comprehension level and knowledge level learning evaluations of comprehension postquestion instructional treatments.

Chapter 3

RESEARCH DESIGN AND PROCEDURE

Subjects

One hundred and twelve high school students enrolled in elementary and intermediate high school chemistry, locally referred to as Chemistry 10 and Chemistry 20, participated in the formal experiment. These students were enrolled at three rural senior high schools located adjacent to the city of Calgary, Alberta. In addition 147 other students participated in pilot studies and were enrolled in two of the same schools and in two other nearby rural schools.

The students, who participated in the experiment, were randomly assigned to one of six groups, as illustrated in Figure 3, Chapter One, p. 19, of this thesis. Three students, who, contrary to the instructions, failed to make any marks in their response booklets, were deemed to be uncooperative and excluded from the data analysis. As a consequence, a total of 109 students, distributed into five groups consisting of 18 students each and one group consisting of 19 students, was used in the final data analysis of the formal experiment.

Pilot Materials

Eight text passages describing eight types of chemical reactions were developed for this study. Each passage con-

sisted of one paragraph explaining a single chemical reaction in general terms followed by two paragraphs each describing an example of the reaction type. These last two paragraphs in each passage included chemical and word equations which incorporated the general information presented in the preceding single paragraph. The passages were one page in length and contained 150 to 300 words.

Postquestions at the knowledge level were also developed targeting three information categories in each of the eight passages. The three information categories focussed upon identification of the reaction type, the reactant-product interrelationship in the reaction, and the completion of word or chemical equations for the chemical reactions. For instance, one of the examples presented in the first passage dealt with the simple composition reaction between elementary nitrogen and elementary hydrogen that produces the molecular compound ammonia and liberates energy. The postquestion; "The reaction between nonmetallic nitrogen and nonmetallic hydrogen is called _____ _____.", required the words "simple composition" to correctly identify the reaction type. Another postquestion; "The reaction between nonmetallic nitrogen and nonmetallic hydrogen produces a molecular _____, ammonia, and _____.", required the knowledge of the products of a simple composition reaction when the reactants were indicated. This question

was correctly answered by completing the blanks with the words "compound" and "energy" respectively. A third post-question required the completion of the following chemical equation: $N_2(g) + 3H_2(g) \longrightarrow$ _____(g) and _____, where "NH_3" and "heat" constituted the correct answers.

Final pilot data analysis suggested the use of six of the eight passages and four types of postquestions querying both knowledge and comprehension learning about the information categories-- reaction identification (or reaction identity) and reactant-product interrelationship. Eight completion (fill-in-the-blank) questions were developed for each of the six passages. Four questions in each set were developed at each of the knowledge and comprehension levels. Questions constructed by rearranging substantive passage words, used to present an example in the passage, evaluated learning at the knowledge level, as indicated by Anderson (1972). A knowledge level question was constructed for each of the two examples contained in the passage, targeting reaction identification information and reactant-product interrelationship information, and resulted in four knowledge level questions for a passage. Four additional questions were constructed in a similar manner to evaluate comprehension of the concepts (Anderson, 1972) presented in the passages. These comprehension questions required students to apply information given in the passage to an

example which was not presented in the passage. (The passages and questions are included in Appendixes A and B, respectively.)

The fifth passage concerning precipitation double replacement reactions is typical of the six passages constructed for this study. This passage is presented below as an example of the passages used in this study. The two knowledge level questions and the two comprehension level questions used as postquestions in each of the categories follow the passage. The passage and corresponding questions are presented here to exemplify the procedure used to develop the four types of questions querying information in each of the six passages.

P-5

PLEASE READ THE FOLLOWING PASSAGE CAREFULLY

Precipitation double replacement reactions characteristically involve the mixing of aqueous solutions of two ionic compounds. The positive metallic ion of one compound exchanges with the positive metallic ion of the second compound and two new compounds are formed. Generally, these reactions are not associated with any energy changes.

Mixing aqueous solutions of ionic silver nitrate and ionic sodium chloride produces a precipitation double replacement reaction. The positive metallic silver ion replaces the positive metallic sodium ion and the solid ionic silver chloride precipitates from the solution. The positive metallic sodium ion replaces the positive metallic silver ion and an aqueous solution of ionic sodium nitrate results.

$AgNO_3$ (aq) + NaCl(aq) → $NaNO_3$(aq) + AgCl(s)

(Chemical Equation)

Silver nitrate	+	Sodium chloride	→	Sodium nitrate	+	Silver chloride
ionic compound solution		ionic compound solution		ionic compound solution		ionic compound solid

(Word Equation)

The precipitation of lead II sulfide from the mixing of lead II nitrate and sodium sulfide solutions is another example of a precipitation double replacement reaction. The metallic positive lead ion replaces the positive metallic sodium ion in the sodium sulfide solution and solid lead II sulfide is formed. The positive metallic sodium ion replaces the positive metallic lead ion in the lead II nitrate ionic solution and the resulting ionic sodium nitrate remains in solution.

$Pb(NO_3)_2$(aq) + Na_2S(aq) → PbS (s) + 2 $NaNO_3$(aq)

(Chemical Equation)

Lead II nitrate	+	Sodium sulfide	→	Lead II sulfide	+	Sodium nitrate
ionic compound solution		ionic compound solution		ionic compound solid		ionic compound solution

(Word Equation)

The knowledge level questions for this passage were based on the silver nitrate with sodium chloride and lead II nitrate with sodium sulfide reactions presented in the passage and could have been answered by remembering the information previously read. The two questions requiring reaction identification information were:

The formation of aqueous ionic sodium nitrate solution and solid ionic silver chloride from aqueous ionic solutions of silver nitrate and sodium chloride is an example of a/an _____ _____ _____ reaction.

The reaction between ionic sodium sulfide and ionic lead II nitrate is called _____ _____ _____.

The following two questions required information focussing upon the reactant-product interrelationship in precipitation double replacement reactions:

The reactants which produced the solid lead II sulfide and ionic sodium nitrate solution were _____ lead II nitrate and ionic _____ _____ solutions.

The reaction between the ionic solutions of silver nitrate and sodium chloride produces ionic sodium _____ and solid _____ _____.

The comprehension level questions required the application of generalized information, obtained from at least one of the three paragraphs contained in each passage, to a new situation. All of these questions were based on chemical reactions different from those used in the specific examples provided in the last two paragraphs of each passage. The following questions required reaction identification information:

The reaction which occurs between ionic potassium sulfide and ionic silver acetate solution is called _____ _____ _____.

The formation of solid barium sulfate and ionic potassium chloride solution that results when aqueous solutions of ionic barium chloride and ionic potassium sulfate are mixed is an example of a _____ _____ _____ reaction.

The reactant-product interrelationship was queried by the questions:

The reactants which produced solid lead II bromide and aqueous potassium acetate must have been ionic _____ of lead II acetate and _____ _____.

The reaction between calcium nitrate and potassium carbonate ionic solution produces _____ calcium carbonate and ionic potassium _____ solution.

Experimental Procedures

Individual booklets were prepared for each student participating in the experiment. The booklets consisted of sheets of paper measuring 21.5 by 28 cm. Each of the six passages was presented on an individual sheet of paper. The following instruction was printed at the top of each passage page: "Please read the following passage carefully.". Separate sheets of paper were used to present two questions querying information on each of the first five passages and eight questions querying information on the sixth passage. All pages presenting questions began with the instruction: "Please answer the questions in the

spaces provided.". A single information cover sheet was stapled to the front of all booklets.

All students were told that the learning materials were designed to predict future success in chemistry problems and tests at high school and college and that the results would be made available to both their class teacher and school principal. Emphasis was placed on the necessity of working through the materials in the order presented in the individual booklets and that re-examination of any pages previously inspected was absolutely forbidden. The students were further informed that the materials would require them either to read a passage carefully or to answer completion type questions. A line was to be inserted in any blank space for which an answer could not be provided. All students were asked to read the same instructional cover sheet (See Appendix C) while the randomly ordered booklets were distributed to the entire class. Students also were provided with a periodic table identical to the one used during regular classroom instruction. The students were asked if they understood the directions before being given permission to begin.

The random distribution of the learning booklets assigned the students to either a placebo control group, a reading-only control group, or to one of four treatment groups; 1. text interspered with knowledge postquestions targeting reaction identification information, 2. text interspersed with knowledge postquestions targeting react-

ant-product interrelationship information, 3. text interspersed with comprehension postquestions targeting reaction identification information, 4. text interspersed with comprehension postquestions targeting reactant-product interrelationship information. Two postquestions of one of the four types (e.g., knowledge level, category one) were inserted after each of the first five passages. Thus all students in the treatment groups received a total of five passages with ten postquestions followed by a sixth passage and a posttest consisting of two questions of each of the four postquestion types querying information about the sixth passage. The reading-only control group received only the six passages and the posttest consisting of the four question types querying information in the sixth passage. The placebo-control group worked at an unrelated task before answering the four question types querying information in the sixth passage. The students in the placebo-control group were never exposed to any of the passages. Posttest questions were scored as correct only if every blank space was correctly completed in the question.

Data Analysis

The posttest scores were evaluated using four separate two-way analyses of variance with knowledge and comprehension posttest scores as repeated measures to determine the presence of significant interactions as described in Chapter One and illustrated in Figure 3. In addition, four

separate one-way analyses of variance tests followed by four Newman-Keuls multiple range tests were used to analyze the control group mean scores compared with the treatment group mean scores as shown in Figure 3. In all respects, the alpha level for these analyses was set at the 0.05 level.

Chapter 4

RESULTS OF THE INVESTIGATION

INTRODUCTION

The experimental study was designed to determine the learning effects on student attending behaviours shaped by postquestions interspersed in written science materials. The postquestions used in the study focussed students' attention on one of two different categories of information concerning chemical reactions and required processing of this information at the knowledge and comprehension levels. Due to the complexity of the hypotheses stated in Chapter One, the hypotheses are restated here, for the convenience of the reader.

It was hypothesized that students assigned to four postquestion treatment groups (independent variables) --knowledge, targeted category one; knowledge, targeted category two; comprehension, targeted category one; comprehension, targeted category two, would differentially respond to four analogous posttest items (dependent variables). Specifically, it was hypothesized that students who were provided with postquestions querying one category of information in a text would attend more to that information category than the non-targeted, alternative category two. Conversely, students who were provided with postquestions querying the alternative category two of information

would attend more to this alternative category. Thus, it was expected that students would correctly answer more posttest items querying the same information category focussed on by the provided postquestion type while answering correctly fewer posttest items querying the information category not focussed on by the provided postquestion type. This general expectation formed the basis for four specific interactive hypotheses dealing with the results of providing:

1. knowledge postquestions and knowledge posttest items.
2. knowledge postquestions and comprehension posttest items.
3. comprehension postquestions and knowledge posttest items.
4. comprehension postquestions and comprehension posttest items.

In other words, the following hypotheses were tested, as illustrated in Figure 4.

1. Students provided with knowledge postquestions will generate higher scores on knowledge posttest items focussing on the targeted information category dealt with in the postquestion. In contrast, students provided with knowledge postquestions will generate lower scores on knowledge posttest items focussing on the nontargeted informa-

GROUPS	POSTTEST ITEMS			
	Knowledge Level		Comprehension Level	
	Category one	Category Two	Category One	Category Two
Knowledge Level Category One	High	Low	High	Low
	X		X	
Knowledge Level Category Two	Low	High	Low	High
	(Hypothesis 1)		(Hypothesis 2)	
Comprehension Level Category One	High	Low	High	Low
	X		X	
Comprehension Level Category Two	Low	High	Low	High
	(Hypothesis 3)		(Hypothesis 4)	
No Questions Reading-Only Control	a	a (Main-Effect Hypothesis 1)	a	a
No Questions or Reading Placebo-Control	b	b (Main-Effect Hypothesis 2)	b	b

a Denotes the same or lower scores than scores in the column above

b Denotes lower scores than all scores in the column above

Figure 4

Analysis of Interactive and Main-Effect Hypotheses

tion category dealt with in the postquestion.

2. Students provided with knowledge postquestions will generate higher scores on comprehension posttest items focussing on the targeted information category dealt with in the postquestion. In contrast, students provided with knowledge postquestions will generate lower scores on comprehension posttest items focussing on the nontargeted information category dealt with in the postquestion.

3. Students provided with comprehension postquestions will generate higher scores on knowledge posttest items focussing on the targeted information category dealt with in the postquestion. In contrast, students provided with comprehension postquestions will generate lower scores on knowledge posttest items focussing on the nontargeted information category dealt with in the postquestion.

4. Students provided with comprehension postquestions will generate higher scores on comprehension posttest items focussing on the targeted information category dealt with in the postquestion. In contrast, students provided with comprehension postquestions will generate lower scores on comprehension posttest items focussing on the nontargeted information category dealt with in the postquestion.

Furthermore, the following main-effect hypotheses were proposed and tested:

1. It was hypothesized that students' performance in the treatment groups on each dependent variable would be the "same" or "higher" than that of the reading only control group.

2. It was hypothesized that students assigned to the reading only control and treatment groups will outperform students assigned to the placebo-control group.

As indicated in Chapter Three, the posttest scores were evaluated using four separate two-way analyses of variance with knowledge and comprehension posttest scores as repeated measures to determine the presence of significant interactions. In addition, four separate one-way analyses of variance tests followed by four Newman-Keuls multiple range tests were used to analyze the control group mean scores compared with the treatment group mean scores as shown in Figure 1. In all respects, the alpha level for these analyses was set at the 0.05 level.

RESULTS OF THE STATISTICAL ANALYSIS

Posttest Performance

The mean proportion of posttest items scored correctly

by all groups is shown in Table 1. The standard deviations for all posttest item scores are summarized in Table 2.

TABLE 1

Mean Proportion Correct on Posttest Item Scores

Groups (Question Level)	Type of Posttest Item			
	Knowledge Level		Comprehension Level	
(Information Category)	Reaction Identity	Reactant Product	Reaction Identity	Reactant Product
Knowledge Reaction Identity	0.72[a]	0.53	0.72[a]	0.42
Knowledge Reactant-Product	0.18	0.42	0.21	0.34
Comprehension Reaction Identity	0.58[a]	0.50	0.67[a]	0.31
Comprehension Reactant-Product	0.33	0.50	0.33	0.50
No Questions Reading-Only Control	0.25	0.36	0.31	0.19
No Reading Placebo-Control	0.00	0.03	0.00	0.00

a Identified group cells generated significantly higher scores relative to no question Reading-Only Control Group

TABLE 2

Standard Deviations on Posttest Item Scores

Group (Question Level) (Information Category)	Type of Posttest Item: Knowledge Level Reaction Identity	Knowledge Level Reactant Product	Comprehension Level Reaction Identity	Comprehension Level Reactant Product
Knowledge Reaction Identity	0.35	0.40	0.39	0.43
Knowledge Reactant-Product	0.38	0.42	0.38	0.44
Comprehension Reaction Identity	0.43	0.45	0.45	0.35
Comprehension Reaction-Product	0.42	0.42	0.42	0.45
No Questions Reading-Only Control	0.43	0.41	0.43	0.30

Interactive Analysis

First, the two separate two-way analyses of variance with repeated measures tests indicated a significant effect for the interaction of the inserted knowledge level question category and type of posttest item at both the knowledge and comprehension levels. The significantly superior posttest performances, $F(1,35) = 8.30$, $p<0.01$, on knowledge posttest questions querying the targeted information category as compared to the nontargeted information category by the treatment groups receiving knowledge postquestions supported the interactive hypothesis 1. Posttest

performances on comprehension posttest questions querying the targeted information category as compared to the nontargeted information category for groups receiving knowledge level targeting postquestions resulted in significant effects, $F(1,35) = 9.52$, $p<0.01$, that supported the interactive hypothesis 2.

Then, a single two-way analysis of variance with repeated measures test of the comprehension posttest scores for the treatment groups which received comprehension level targeting postquestions showed significant effects, $F(1,34) = 11.51$, $p<0.01$, for the targeted information category as compared to the nontargeted information category. This result supported the interactive hypothesis 3.

Finally, the knowledge level posttest scores for the treatment groups receiving comprehension level targeting postquestions did not show significant effects, $F(1,34) = 2.68$. Of less importance, the means of the targeted information category on knowledge level posttest scores of the treatment groups which received comprehension postquestions did, however, indicate a trend toward superior performances, as compared to the means of the nontargeted information category, predicted in the interactive hypothesis 4.

Main Effects Analysis

The four separate one-way analyses of variance tests used to analyze the control group mean scores compared with the treatment group mean scores showed significantly superior results for only the treatment groups receiving postquestions

targeting reaction identification information at the knowledge level, $F(4,86) = 5.90$, $p<0.01$, and the comprehension level, $F(4,86) = 5.63$, $p<0.01$. The Newman-Keuls multiple range tests indicated that none of the treatment group mean scores were significantly lower than the control group mean scores, as had been predicted in the first main-effect hypothesis.

These multiple range tests further indicated significantly superior performances, compared to the reading only control group, on reaction identification knowledge level posttest items for treatment groups targeted by reaction identification knowledge level and comprehension level postquestions. In addition, the reaction identification knowledge level and comprehension level postquestion treatment groups performed significantly better than the reading only control groups on reaction identification comprehension level posttest items. The only reactant-product category postquestion group shown to be significantly above the range of the reading-only control group was the group receiving the comprehension level postquestion treatment for the reaction identification knowledge level posttest items. All other reactant-product postquestion treatment group posttest scores were in the same range as the scores of the reading-only control group.

The second main-effect hypothesis was supported by inspection of the mean proportion correct scores on the four types of posttest items indicated in Tables 1 and 2.

Chapter 5

INTERPRETATION AND IMPLICATIONS OF THE STUDY

INTRODUCTION

This study investigated the indirect learning effects produced by focussing students' attention on specific categories of information encountered during the reading of written chemistry materials similar to those used in regular science classrooms. The effectiveness of interspersed knowledge level and comprehension level postquestions in promoting the learning of information not actually questioned during the experimental treatments was examined in terms of interactive and main effects.

An interaction was hypothesized for the type of postquestion and type of posttest item. Specifically, students provided with knowledge level postquestions targeting a restricted category of information were expected to perform better on posttest items querying the targeted information category than on posttest items querying the nontargeted information category. Other students provided with comprehension level postquestions targeting restricted categories of information were similarly expected to perform better on posttest items querying the targeted information category than on posttest items querying the nontargeted information category. The same posttest items evaluating

knowledge and comprehension levels of learning were answered by both student groups.

Furthermore, superior or similar posttest performance was predicted for students who received interspersed postquestions as compared to those who only read the passages and received no questions. In addition, the students who received postquestions or who were allowed to read the passages without postquestions were expected to outperform those students who answered the posttest questions but were not exposed to the passages or the postquestions.

SUMMARY OF THE RESULTS

As predicted, students in the two treatment groups questioned at the knowledge level for two information categories were significantly more accurate in their responses to knowledge level posttest items different in specific content but from the same categories of inserted postquestion that in their posttest item responses of categories different from the inserted postquestions. Moreover, these students targeted by knowledge level postquestions also performed significantly better on the comprehension posttest items querying the same information category of inserted postquestion than on the comprehension posttest items querying a different category of information.

Consistent with the additional prediction, the two

postquestion treatment groups targeted for the specific categories of information by comprehension level postquestions performed significantly better on comprehension level posttest items from the same information category of inserted postquestion relative to the information categories different from those queried in the inserted postquestions. These comprehension level postquestion treatment groups performed better on knowledge level posttest items from the targeted information category than the nontargeted information category but this performance did not reach the predicted level of significance.

The prediction that postquestion treatment groups would perform as well as the reading-only control group within both information categories on knowledge level and comprehension level posttest items, was substantiated by Newman-Keuls multiple range tests. The treatment groups targeted for the reaction identification information category by the knowledge level and the comprehension level inserted postquestions performed significantly better than the reading-only control groups on posttest items of this category at both levels of learning. In addition, the performance of the treatment groups and the reading-only control group exceeded that of the placebo control group.

DISCUSSION OF THE RESULTS

Student performance in restricted categories of information presented by written materials appeared to be enhanced by the insertion of questions consistently querying specific types of information contained in a series of passages. The posttest evaluation used in this study queried specific content information found in the last passage and not previously questioned information. As a consequence, the measured student performance reflected an indirect learning effect. Rickards' (1979) analysis of the processes produced by postquestions in the studies he reviewed suggested that the indirect effect demonstrated in this study would occur when postquestions asking for restricted categories of information were repeatedly presented to students.

Correct posttest item responses on the new content presented in the sixth passage might have resulted from backward processing due to a mental review of this information initiated by the questions encountered on the page after the passage. Such a backward review, however, would be expected to produce similar effects on all information categories. The demonstrated differential effect, favoring posttest responses in the category of information queried by postquestions inserted after previously encountered passages, would more likely have resulted from increased attention toward the specific information category during the reading of

the sixth passage. In other words, the experimental data suggested that students in the postquestion treatment groups anticipated the kind of information on which they would be tested and focussed attention on the category of information perceived as important. This anticipatory nature of the processing activities engaged by the learner presented with written learning materials is consistent with the selective attention model proposed by Rothkopf (1965) and supported in the related literature.

Differential posttest responses for specific categories of information presented in the sixth passage can be attributed to a gradual shaping of student processing activities. Postquestions used in the successive passages of this experiment likely served to cue and reinforce selective attentional behaviours. Students were able to develop a reasonable learning strategy for dealing with the reading materials after the first passages based on the cues provided by the repetition of similar questions. Postquestions encountered after subsequent passages provided students with information required to confirm, modify, or reject this adopted learning strategy. In all events, the processing activities engaged by the students can be seen to have operated in the forward direction as successive passages were read. The learning set, focussing attention on specific restricted categories of information, was sufficiently established to produce significantly superior learning of the targeted

category of information compared to the learning of the non-targeted category of information, presented by the sixth passage, for three of the experimental conditions.

These results are consistent with the effects, indicated by Rickards (1979), of specific forward processing. Moreover, the significant interaction of knowledge level postquestions from a specific information category and knowledge level posttest items of the same category, shown in this study using written science materials, demonstrated similar results to those reported by Reynolds, Standiford, and Anderson (1979) in new posttest items using a narrative non-science prose passage.

The learning of specific categories of information displayed by the students receiving postquestions querying examples presented in the passages was apparently readily transferred to items presenting new examples of the same concept. Particular attention to the targeted information category enabled students to respond differentially to the posttest items questioning this specific category of information required in the new examples as well as in the familiar examples.

When these results are considered from the "depth of processing" viewpoint (Craik and Lockhart, 1972), knowledge level postquestions should produce orthographic or phonological encoding of the targeted information. Student performance on the comprehension posttest items, however, re-

flected semantic encoding of the information presented in the passage. Yet, Anderson (1972) contended that students do not usually process learning material beyond the level that is required by the instructional task.

The transfer-appropriate-processing notion, on the other hand, suggested that information encoded during instruction becomes meaningful to a student when processing strategies used to answer instructive postquestions could be transferred to learning evaluation tasks. Successful performance on the posttest items of this study largely depended on thorough processing of the cues establishing the information category. Two different examples were presented in each passage and as the examples used in each of the six passages were also different, attention to the information category was probably an easier and more effective strategy than attempting to remember all specific details related to each example. The strategy of focussing attention on the characteristics of the information category would be easily transferred from the content presented in one passage to the content presented in the next passage. This strategy could be just as easily transferred to the new examples as to the familiar examples used in the posttest items following the sixth passage. Consequently posttest performance on items dealing with new content resulted in similarly focussed knowledge level and comprehension level responses.

The use of comprehension level targeting postquestions, from the transfer-appropriate-processing perspective, initiated similar learning strategies to those theorized for the knowledge level targeting postquestions. Such similar strategies resulted in the superior posttest performance on comprehension posttest items in the targeted information categories compared to the nontargeted information categories.

Students in the comprehension level postquestion treatment groups could be expected to transfer the learning strategy developed to deal with new examples to knowledge questions dealing with examples already seen in the sixth passage. These repeated example questions were simply more questions requiring the application of the targeted information category. However, students in the comprehension level postquestion groups were evidently familiar with the nontargeted information relating to the repeated examples. This familiarity, as demonstrated by responses to the knowledge level posttest items, may have been due to a difference in the processing strategy used during the comprehension level instructional task. Students presented with comprehension level postquestions would have had to generalize from the examples they read about in the passage to new examples every time they encountered the postquestions dealing with new examples after each passage. The processing may have required more intensive attention to the speci-

fic examples presented in the passage and produced a latent capability to answer questions dealing with the details relating to the nontargeted information in the repeated examples but not in the new examples. Students targeted with knowledge level postquestions, on the other hand, would more simply have been able to isolate the targeted information category from the examples without having to generalize this information to new examples until after the learning set to attend to specific information categories was well established.

The posttest performance of postquestion treatment groups, in this study, relative to the posttest performance of control groups, justified McConkie's (1977) concern with task ambiguity. In all instances, postquestion groups scored in the same "ranges" as the reading-only control group. Students in postquestion treatment groups targeting specific information categories were given sufficient practice at the instructional task to enable them to clearly define their perceptions of the task requirements.

In this study, nontargeted category posttest scores were all in the same "range" as those of the reading-only control posttest scores. These results reflected the similar treatments received by the reading-only control students and the postquestion group students. Whereas the reading-only control group received no questions for all information, the postquestion groups received no questions for

nontargeted information. Postquestion groups expended similar attentional efforts during reading nontargeted information as did the reading-only control group. In other words, students in postquestion groups clearly perceived that acquiring information related to the nontargeted category was not part of their instructional task.

Students targeted by reaction identification postquestions significantly outperformed the reading-only control group on reaction identification posttest items. Reaction-identification information received greater attention during reading in this condition, because students were assured that acquiring such information was important in their instructional task.

Posttest scores of students targeted by reactant-product postquestions were in the same "range" as those of the reading-only control students. However, the posttest scores on reactant-product posttest items were higher than those of the reading-only control group. Whereas the reaction identification postquestions consistently required the identification of the chemical reaction type, the reactant-product postquestions alternately required reactant information and product information. Students in the reactant-product postquestion groups would, therefore, have experience greater difficulty in defining their instructional task. This increased ambiguity in task structure perhaps resulted in reactant-product posttest scores that were depressed below the

potential level.

IMPLICATIONS RELATED TO EDUCATIONAL PRACTICE

Science teachers frequently use questions to assist student learning from written materials. The questions used, however, most often query a wide range of information within a specific science concept. Rarely are questions designed to consistently focus attention on selective kinds of information.

Considerable indirect learning can evidently result from a learning set induced by questions constructed to focus student attentional processing. The learning of specific information for which direct instruction is not required is often considered desirable by educators. Such learning is economical in terms of time and effort while additionally fostering student independence. A learning set, however, differentially affects categories of information. Learning of targeted information may occur at the expense of learning other information although the results of this study indicated that the learning of nontargeted information was similar to that achieved when no questions were provided during reading.

Presentations of conceptually related information can be effectively designed to convey vast amounts of accumulated knowledge. Study questions, through the influence of

a learning set, can focus students' processing activities on trivial or undesired aspects of science information. Instructional designers and science educators should be aware of the importance of determining which information they most want students to learn. Study questions should be designed to promote attentional processing of conceptually significant information.

Science teachers and text designers should also give serious consideration to the extent instructional materials and study questions help students unambiguously define instructional tasks. Ambiguity of task structure can depress potential effects of a desired learning set. Too few practice questions in an instructional task can create confusion in students' perceptions of required tasks. Conversely, too many practice questions requiring tangentially related information can unintentionally induce an undesirable learning set.

Science educators have generally been concerned with the promotion of comprehension level learning. Greater educational significance is associated with student application of scientific concepts than with student recall of scientific facts. Educators widely believe (Andre, Mueller, Womack, Smid, and Tuttle, 1980) that higher-order questions produce superior learning of concept application. The findings in this study suggested that lower-order knowledge level questions were as effective as higher-order comprehen-

sion level questions in producing application of concepts in new examples when conditions enhanced students' focussing behaviours. The present results, in conjunction with the results of Andre et al. (1980) suggested that science teachers and authors of textbooks might be justified in using knowledge or factual questions during instructional tasks until further question investigations conclusively determine conditions under which higher-order questions produce superior facilitation of application learning. At an rate, further work in this area is needed before any classroom recommendations can be made to science teachers.

RECOMMENDATIONS FOR FUTURE RESEARCH

The results of the present study suggested that a learning set can strongly influence students' attentional processing during the reading of science prose material. Focussing behaviours of students studying conceptually related information apparently can determine what is learned from similar presentations encountered later. Further research is required to determine the durability of a learning set established by targeting postquestions. A learning set to attend to selective information seemingly could help students isolate important information during more advanced studies. On the other hand, such learning sets may persist for only a short time and require re-establishment each time similar conceptual information is encountered. Delayed

evaluations of targeted information categories are therefore recommended, particularily when other concepts have been presented during the intervening time period.

The focussed indirect learning demonstrated using the present written science material, should be further explored in conjunction with other media used in science education. Holliday and Benson (1981) have demonstrated strongly focussed direct learning using an instructional chart-table. Features such as chart-tables, graphical representations, and flow diagrams are often used to summarize and emphasize science concepts presented in prose sections of science textbooks. The redundant information supplied by such presentations may enhance the establishment of a learning set. Comparative studies using written materials and a chart-table, written materials alone, and a chart-table alone might help determine the influence of such presentations on students' focussing behaviours.

Although, the present study investigated indirect learning effects of specific forward processing, few investigations of general forward processing have been reported. McGaw and Grotelueschen (1972), however, showed increased learning of general information following postquestions. The selective attention model predicted that students receiving postquestions would increase their attention to all text information following postquestions in anticipation of further questions following this textual information.

How such attentional processing influences focussing behaviours has yet to be examined.

Further investigation of the learning effects of various types of questions is also recommended. The conditions under which lower-order and higher-order questions facilitate meaningful learning and retention have not been clearly delimited. The studies reported by Andre, Mueller, Womack, Smid, and Tuttle (1980) raised serious doubts that the encoding view accurately represents the way different kinds of questions function in learning situations. The present study supported the results obtained by Andre et al. (1980) to the extent that similar comprehension level focussing behaviours were produced by both knowledge level and comprehension level instructional postquestions. However, the failure to show significant knowledge level focussing by comprehension level instructional questions suggested that a different kind of learning process may be induced by comprehension level postquestions. This issue needs clarification. In view of the confidence that many current educational practitioners place in the superior learning facilitation of comprehension questions, future research studies contributing to better understanding of the learning processes induced by these types of questions are important.

In summary, further research investigations will assist educational researchers in determining the significance of student focussing behaviours in the learning process. More

effective educational practice can result from an understanding of the interrelationship of learner, instructional materials, instructional tasks and learning activities. Indeed, what the learner does with learning materials largely determines what is learned (Rothkopf, 1970).

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APPENDICES

APPENDIX A

TEXT DESCRIPTION OF THE SIX TYPES OF CHEMICAL REACTIONS

P-1

Chemical reactions in which two or more elements combine to produce a single compound are called simple composition reactions. Ionic compounds are produced in a reaction between metallic and nonmetallic elements whereas molecular compounds are produced when two nonmetallic elements react. These simple composition reactions generally involve the production of energy in the form of heat or light.

The burning of steel wool, which contains elementary iron, in the oxygen supplied by air, is an example of a simple composition reaction which produces an ionic compound.

$4\ Fe(s) + 3\ O_2(g) \longrightarrow 2\ Fe_2O_3(s)$ + shower of hot sparks

(Chemical Equation)

Iron metal + oxygen nonmetal ⟶ Iron II oxide Ionic compound + heat and light energy

(Word Equation)

Nonmetallic nitrogen, found in air, will combine with nonmetallic hydrogen, to produce the molecular compound, ammonia, NH_3. This is another example of a simple composition reaction.

$N_2(g) + 3H_2(g) \longrightarrow 2\ NH_3(g)$ + heat

(Chemical Equation)

Nonmetal nitrogen + Nonmetal hydrogen ⟶ ammonia molecular compound + energy

(Word Equation)

P-2

Simple decomposition reactions are those in which a compound is decomposed or broken down into its constituent elements. Ionic compounds decompose into metallic and nonmetallic elements whereas molecular compounds decompose into two nonmetallic elements. These simple decomposition reactions require the addition of energy in the form of heat, light, or electricity.

$$2\ HgO\ (s) + heat \longrightarrow 2Hg(l) + O_2(g)$$

(Chemical Equation)

Mercury II oxide (Ionic compound) + energy → metallic mercury + nonmetallic oxygen

(Word Equation)

The molecular compound, phosphorus trihydride, PH_3, undergoes simple decomposition to produce nonmetallic phosphorus and nonmetallic hydrogen.

$$4\ PH_3(g) + heat \longrightarrow P_4(s) + 6\ H_2(g)$$

(Chemical Equation)

Phosphorus trihydride (Molecular compound) + energy → nonmetallic phosphorus + nonmetallic hydrogen

(Word Equation)

P-3

Organic compounds frequently are involved in burning or combustion reactions that liberate both heat and light energy. Two common types of organic compounds are hydrocarbons and carbohydrates. Hydrocarbons are composed solely of carbon and hydrogen atoms whereas carbohydrates contain carbon, hydrogen, and oxygen atoms. These organic compounds will burn in oxygen to produce carbon dioxide, water vapor, and energy.

Wax burned in candles contains the hydrocarbon, paraffin, $C_{25}H_{52}$. The carbon and hydrogen atoms combine with the available oxygen atoms to produce carbon dioxide, water vapor, and large amounts of energy in this hydrocarbon combustion reaction.

$$C_{25}H_{52}(s) + 38\ O_2(g) \longrightarrow 25\ CO_2(g) + 26\ H_2O(g) + \text{heat} + \text{light}$$

(Chemical Equation)

Paraffin Hydrocarbon + oxygen ⟶ Carbon dioxide + water vapor + energy

(Word Equation)

The carbohydrate, glucose, $C_6H_{12}O_6$, commonly found in many foods, is burned by the body to produce energy in a carbohydrate combustion reaction.

$$C_6H_{12}O_6(s) + 6\ O_2(g) \longrightarrow 6\ CO_2(g) + 6\ H_2O(g) + \text{energy}$$

(Chemical Equation)

Glucose Carbohydrate + oxygen ⟶ carbon dioxide + water vapor + energy

(Word Equation)

P-4

One of the constituent elements in an ionic compound can be replaced by a free element in a type of reaction called single replacement. Metallic elements can replace metallic ions in an ionic compound whereas nonmetallic elements can replace nonmetallic ions in an ionic compound. The reaction produces a different ionic compound and the replaced ion is liberated as either a free metallic or nonmetallic element. Single replacement reactions generally occur at room temperature with no evidence of energy changes.

A spongy mass of shiny metallic silver can be produced when metallic copper is put into an ionic silver acetate solution. As this single ion replacement reaction proceeds, ionic copper II acetate solution is formed by the replacement of the metallic silver ion with the metallic copper ion.

$$Cu(s) + 2AgCH_3COO(aq) \longrightarrow Cu(CH_3COO)_2(aq) + 2\ Ag$$

(Chemical Equation)

Metallic Copper + silver acetate ionic compound → Copper II acetate ionic compound + metallic silver

(Word Equation)

The nonmetal, iodine, can be produced when chlorine water is added to a solution of ionic sodium iodide. The nonmetallic chloride ion replaces the nonmetallic iodide ion in this single ion replacement reaction.

$$Cl_2(aq) + 2\ NaI(aq) \longrightarrow 2\ NaCl(aq) + I_2(s)$$

(Chemical Equation)

Nonmetallic Chlorine + sodium iodide ionic compound → sodium chloride ionic compound + nonmetallic iodine

(Word Equation)

P-5

Precipitation double replacement reactions characteristically involve the mixing of aqueous solutions of two ionic compounds. The positive metallic ion of one compound exchanges with the positive metallic ion of the second compound and two new compounds are formed. Generally, these reactions are not associated with any energy changes.

Mixing aqueous solutions of ionic silver nitrate and ionic sodium chloride produces a precipitation double replacement reaction. The positive metallic silver ion replaces the positive metallic sodium ion and the solid ionic silver chloride precipitates from the solution. The positive metallic sodium ion replaces the positive metallic silver ion and an aqueous solution of ionic sodium nitrate results.

$AgNO_3(aq) + NaCl(aq) \longrightarrow NaNO_3(aq) + AgCl(s)$

(Chemical Equation)

Silver nitrate ionic compound solution + sodium chloride ionic compound solution → sodium nitrate ionic compound solution + silver chloride ionic compound solid

(Word Equation)

The precipitation of lead II sulfide from the mixing of lead II nitrate and sodium sulfide solutions is another example of a precipitation double replacement reaction. The metallic positive lead ion replaces the positive metallic sodium ion in the sodium sulfide solution and solid lead II sulfide is formed. The positive metallic sodium ion replaces the positive metallic lead ion in the lead II nitrate ionic solution and the resulting ionic sodium nitrate remains in

solution.

$Pb(NO_3)_2(aq) + Na_2S(aq) \longrightarrow PbS(s) + 2\ NaNO_3(aq)$

(Chemical Equation)

Lead II nitrate ionic compound solution + sodium sulfide ionic compound solution → Lead II sulfide compound solid + sodium nitrate ionic compound solution

(Word Equation)

P-6

Acid neutralization reactions are accompanied by an increase in temperature resulting from the production of energy in the form of heat. Common acids contain positive hydrogen ions and nonmetallic simple or complex ions. Common bases contain metallic ions and the nonmetallic hydroxide (OH^-) complex ion. Acid neutralization reactions involve the replacement of the metallic ion of the base with the hydrogen ion of the acid to produce water. The metallic ion of the base takes the place of the hydrogen ion of the acid and a new ionic compound is produced.

Hydrochloric acid, HCl, reacts with the base, sodium hydroxide, in an acid neutralization reaction. The reaction produces an ionic compound, sodium chloride, water, and heat.

$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l) + heat$

(Chemical Equation)

Hydrochloric acid + sodium hydroxide Basic solution → sodium chloride compound solution + water + heat

(Word Equation)

Chloric acid, $HClO_3$, reacts with the base, potassium

hydroxide, to produce an ionic compound, water, and energy in an acid neutralization reaction.

$HClO_3$ + KOH(aq) $\longrightarrow$ $KClO_3$(aq) + H_2O(l) + heat

(Chemical Equation)

Chloric acid + Potassium hydroxide Basic solution $\longrightarrow$ Potassium chlorate ionic compound solution + water + energy

(Word Equation)

APPENDIX B

QUESTIONS USED IN THE STUDY

ORGANIZATION OF APPENDIX B

Four postquestion types used after training passages one to five are presented in the following order:

Questions	Level	Category
1 and 2	Knowledge	Reaction Identification
3 and 4	Knowledge	Reactant-Product
5 and 6	Comprehension	Reaction Identification
7 and 8	Comprehension	Reactant-Product

Posttest items used after transfer passage six are presented in the random order used in the experiment.

P-1

1. The production of iron II oxide from metallic iron and nonmetallic oxygen is an example of a/an _____ _____ reaction.
2. The reaction between nonmetallic nitrogen and nonmetallic hydrogen is called _____ _____.
3. The reactants which produced the ionic compound, iron II oxide and a shower of hot sparks, must have been the metallic elements, _____ and _____ elementary oxygen.
4. The reaction between nonmetallic nitrogen and nonmetallic hydrogen produces a molecular _____, ammonia, and _____.
5. The reaction which occurs when metallic sodium is heated with pure nonmetallic sulfur is called _____ _____.
6. The production of dinitrogen tetraoxide, N_2O_4, from nonmetallic nitrogen and nonmetallic oxygen is an example of a/an _____ _____ reaction.
7. The reactants which produced the molecular compound phosphorus trihydride, PH_3, and heat must have been nonmetallic _____ and _____ hydrogen.
8. The reaction between metallic aluminum and nonmetallic flourine produces _____ compound aluminum flouride and _____.

P-2

1. The production of nonmetallic phosphorus and nonmetallic hydrogen gas from the heating of phosphorus trihydride is an example of a/an _____ _____ reaction.
2. The reaction resulting from the heating of mercury II oxide is called _____ _____.
3. The reactants which produced nonmetallic phosphorus and nonmetallic hydrogen gas must have been _____ _____ phosphorus trihydride and _____.
4. The reaction between ionic mercury II oxide and heat produces _____ metal and oxygen _____.
5. The reaction which occurs when copper II sulfide is roasted by heating is called _____ _____.
6. The production of nonmetallic nitrogen and nonmetallic iodine from the heating of nitrogen triiodide is an example of a/an _____ _____ reaction.
7. The reactants which produced nonmetallic carbon and nonmetallic oxygen must have been molecular _____ _____ and _____.
8. The reaction between heat and ionic zinc oxide produces zinc _____ and _____ nonmetal.

P-3

1. The formation of carbon dioxide gas, water vapor, and energy during the burning of paraffin, $C_{25}H_{52}$, in oxy-

gen is an example of a/an _____ _____ reaction.

2. The burning reaction of glucose, $C_6H_{12}O_6$, in oxygen is called _____ _____.
3. Propane, C_3H_8, and oxygen, O_2, will produce _____ _____, _____ and _____ when they react.
4. The reaction between glucose, $C_6H_{12}O_6$ and oxygen produces _____ _____, _____ and _____.
5. The reaction which occurs when octane, C_8H_{18}, is burned in oxygen is called _____ _____.
6. The production of carbon dioxide, water, and energy from the reaction between sucrose, $C_{12}H_{22}O_{11}$, is an example of a/an _____ _____ reaction.
7. The reaction between raffinose, $C_{18}H_{32}O_{16}$, and oxygen produces _____ _____, _____ and _____.
8. Acetylene, C_2H_2, and oxygen will produce _____ _____, _____ and _____ when they react.

P-4

1. The formation of copper II acetate and silver from metallic copper and ionic silver acetate solution is an example of a/an _____ _____ _____

reaction.

2. The reaction between nonmetallic chlorine and ionic sodium iodide solution is called _____ _____ _____.

3. The reactants which produced the ionic compound copper II acetate and metallic silver must have been the metallic element _____ and _____ _____.

4. The reaction between nonmetallic chlorine and ionic sodium iodide produces ionic _____ _____ _____ and _____ nonmetal.

5. The reaction which occurs when metallic potassium is put into ionic tin II nitrate solution is called _____ _____ _____.

6. The production of magnesium chloride and bromine from nonmetallic chlorine and ionic magnesium bromide is an example of a/an _____ _____ _____ reaction.

7. The reaction which produced ionic potassium chloride and metallic aluminum must have been _____ potassium and _____ aluminum chloride.

8. The reaction between nonmetallic fluorine and ionic potassium bromide produces _____ _____ and _____ _____.

P-5

1. The formation of aqueous ionic sodium nitrate solution and solid ionic silver chloride from aqueous ionic solutions of silver nitrate and sodium chloride is an example of a/an _____ _____ _____ reaction.
2. The reaction between ionic sodium sulfide and ionic lead II nitrate is called _____ _____ _____.
3. The reactants which produced the solid lead II sulfide and ionic sodium nitrate solution were _____ _____ lead II nitrate and ionic _____ _____ solutions.
4. The reaction between the ionic solutions of silver nitrate and sodium chloride prodices ionic sodium _____ and solid _____ _____.
5. The reaction which occurs between ionic potassium sulfide and ionic silver acetate solutions is called _____ _____ _____.
6. The formation of solid barium sulfate and ionic potassium chloride solution that results when aqueous solutions of ionic barium chloride and ionic potassium sulfate are mixed is an example of a _____ _____ _____ reaction.
7. The reactants which produced solid lead II bromide and aqueous potassium acetate must have been ionic _____

of lead acetate and _____ _____.

8. The reaction between calcium nitrate and potassium carbonate ionic solution produces _____ calcium carbonate and ionic potassium _____ solution.

P-6 (Posttest)

1. The reactants which produced ionic magnesium nitrate solution, water, and heat must have been _____ _____ and magnesium hydroxide.
2. The production of sodium chloride solution, water, and energy from the mixing of aqueous hydrochloric acid and aqueous sodium hydroxide solutions is an example of a/an _____ _____ reaction.
3. The reaction between chloric acid and ionic solution of potassium hydroxide produces ionic _____ _____, and _____ and _____.
4. The reaction which occurs when aqueous solutions of potassium hydroxide and hydrobromic acid are mixed is called _____ _____.
5. The reaction resulting from the mixing of aqueous chloric acid and aqueous potassium hydroxide solutions is called _____ _____.
6. The reaction between sulfuric acid and aqueous ionic barium hydroxide produces _____ _____ ionic solution, _____ and _____.

7. The reactants which produced ionic sodium chloride solution, water, and heat were _____ _____ basic solution and _____ _____.

8. The production of lithium sulfate, water, and heat resulting from the mixing of aqueous solutions of sulfuric acid and lithium hydroxide is an example of a/an _____ _____ reaction.

APPENDIX C

INSTRUCTIONAL COVER SHEET GIVEN TO ALL EXPERIMENTAL STUDENTS

These materials are designed to indicate how well you will do in Chemistry problems and tests at high school and college.

Please work through these materials in the order in which they are arranged. Some pages simply require you to read the information printed on the page. Make certain that you read this information carefully. Other pages require you to answer fill-in the blank questions based on the information given in the passage. One word is required for each blank. You will find some of these questions extremely easy; others you may not be able to answer. If you cannot answer a question or a part of a question simply draw a line in the blank space and proceed to the next question.

Once you have completed a page and have turned to the following page you MUST NOT TURN BACK TO ANY PAGES ALREADY COMPLETED.

It is important that you attempt to complete all of the tasks to the best of your ability.